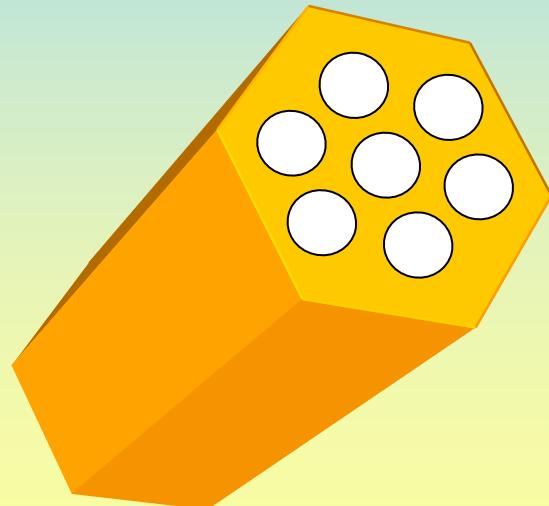


Nanostructured functional materials via organic thin films - what can we learn from x-ray scattering techniques ?



Detlef-M. Smilgies

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cell membranes

MEDICINE

medical
implants

MATERIALS

molecular
electronics

*Organic
Thin
Films*

BIOLOGY

supramolecular
chemistry

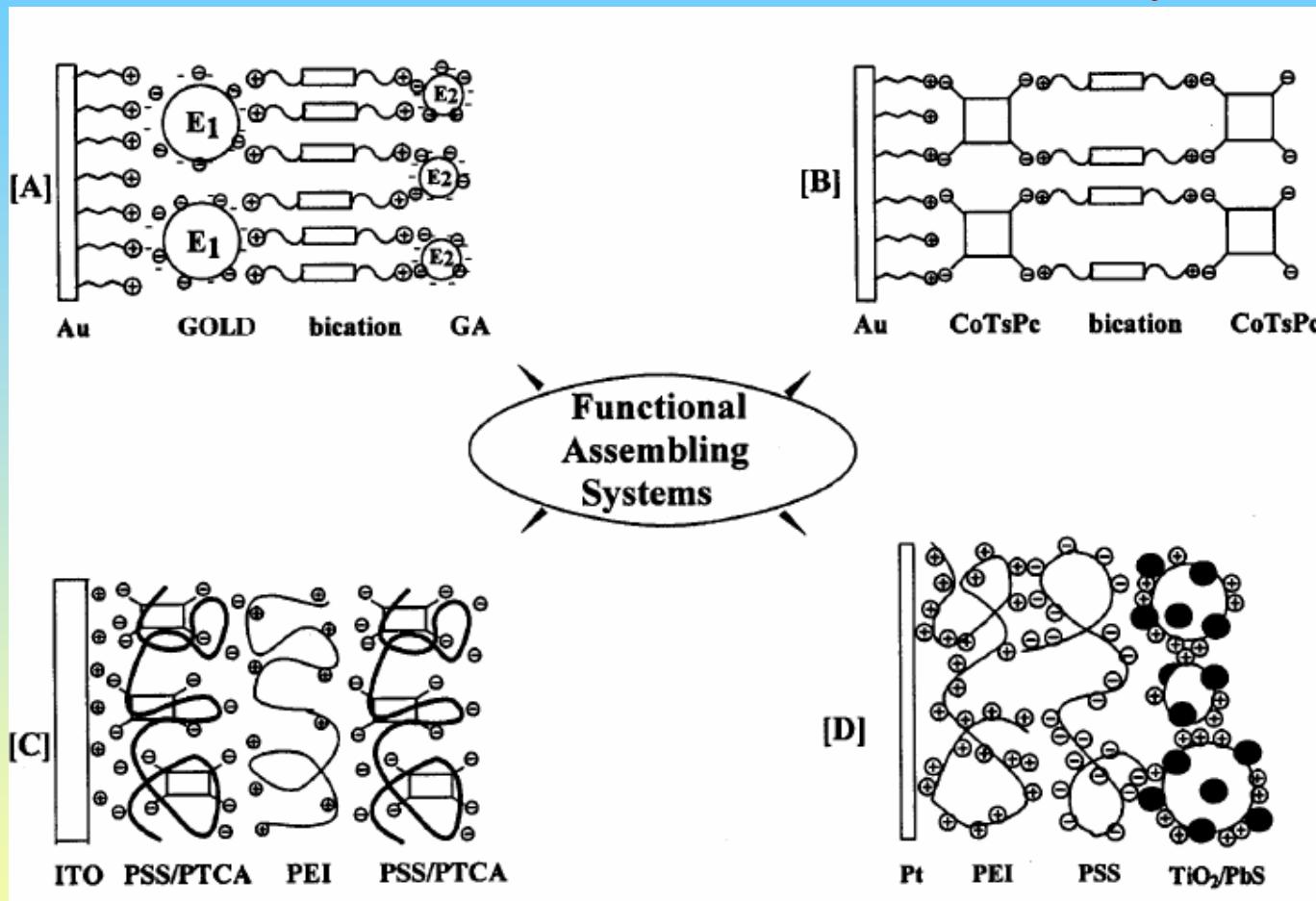
CHEMISTRY

soft condensed
matter

PHYSICS

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Functional assemblies: examples



[A] biosensor [B] chemical sensor [C] OLED [D] solar cell

Zhang and Shen, Advanced Materials 11, 1139-1143 (1999).

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Self-organization processes

Chemical : specific bonding

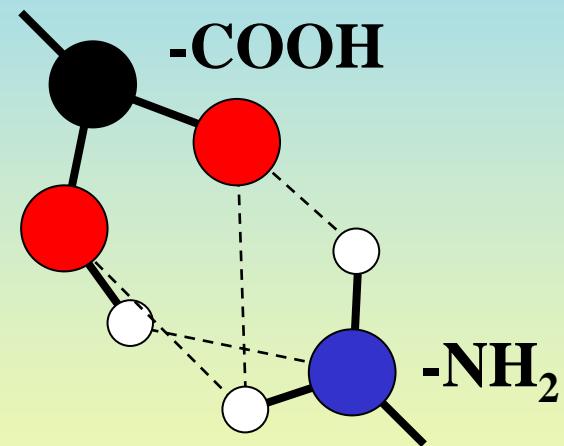
- hydrogen bonds: $-\text{COOH} - \text{NH}_2 -$
- coordination chemistry: $-\text{tpy} - \text{Co}^{2+} - \text{tpy}-$
- self-assembled monolayers: thiols/gold

Biological

- DNA base pairing
- protein – enzyme
- antigen – virus

Physical

- electrostatic (colloids, polyelectrolytes)
- hydrophobic/hydrophilic (surfactants)
- interface energy & entropy (block copolymers)



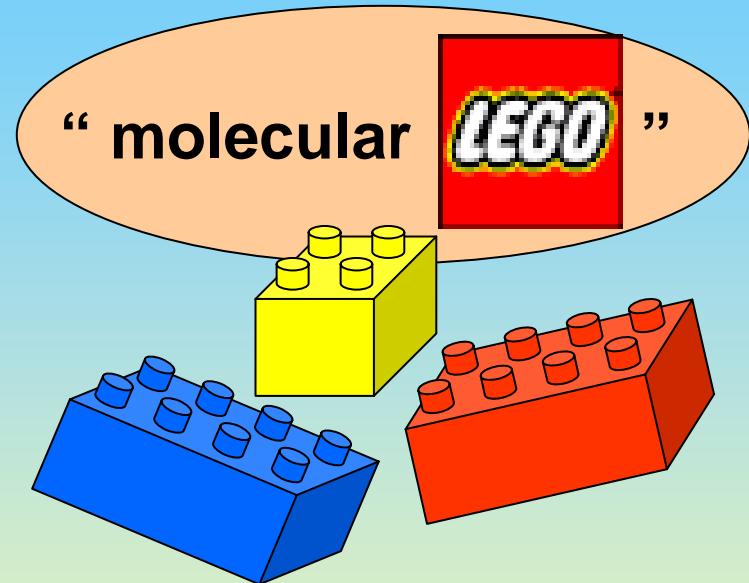
Functional assemblies: building principles

Functional components

- nanoparticles
- fluorescent molecules
- enzymes
- etc

Structural components

- block copolymers : embedding
- surfactant mesophases : embedding
- polyelectrolytes : embedding
- functionalized SAMs : anchoring
- etc



Grazing-Incidence SAXS

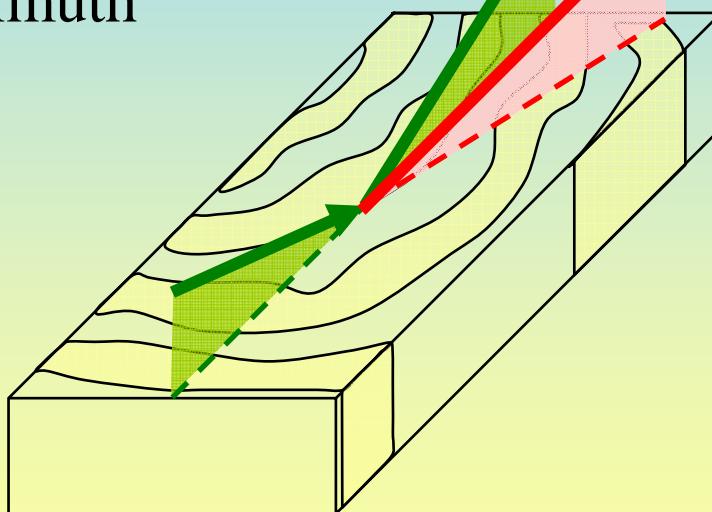
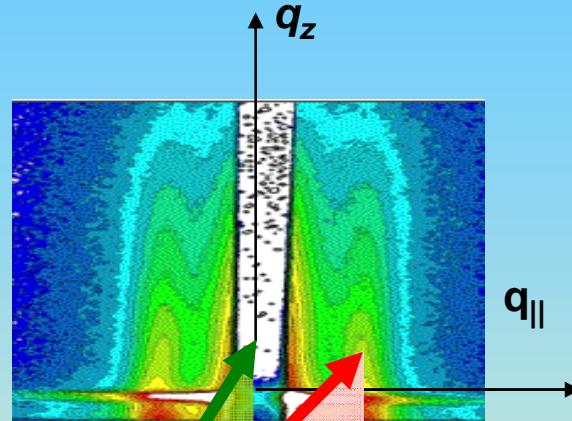
GISAXS map: $I(\alpha, \psi, \beta, \phi)$

α : incident angle

ψ : in-plane scattering angle

β : exit angle

ϕ : sample azimuth



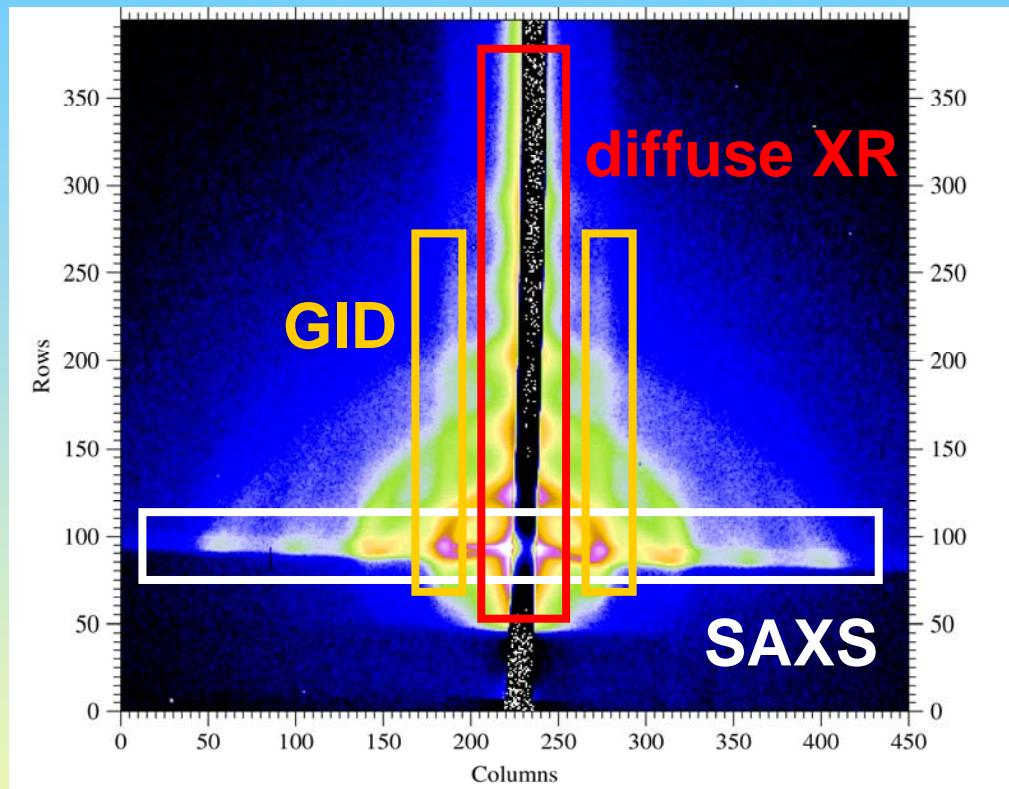
applications:

- surfaces
- thin films
- buried layers

Levine *et al.*, J. Vac. Sci. Technol. A6, 1771 (1988); J. Appl. Cryst. 22, 528(1989).

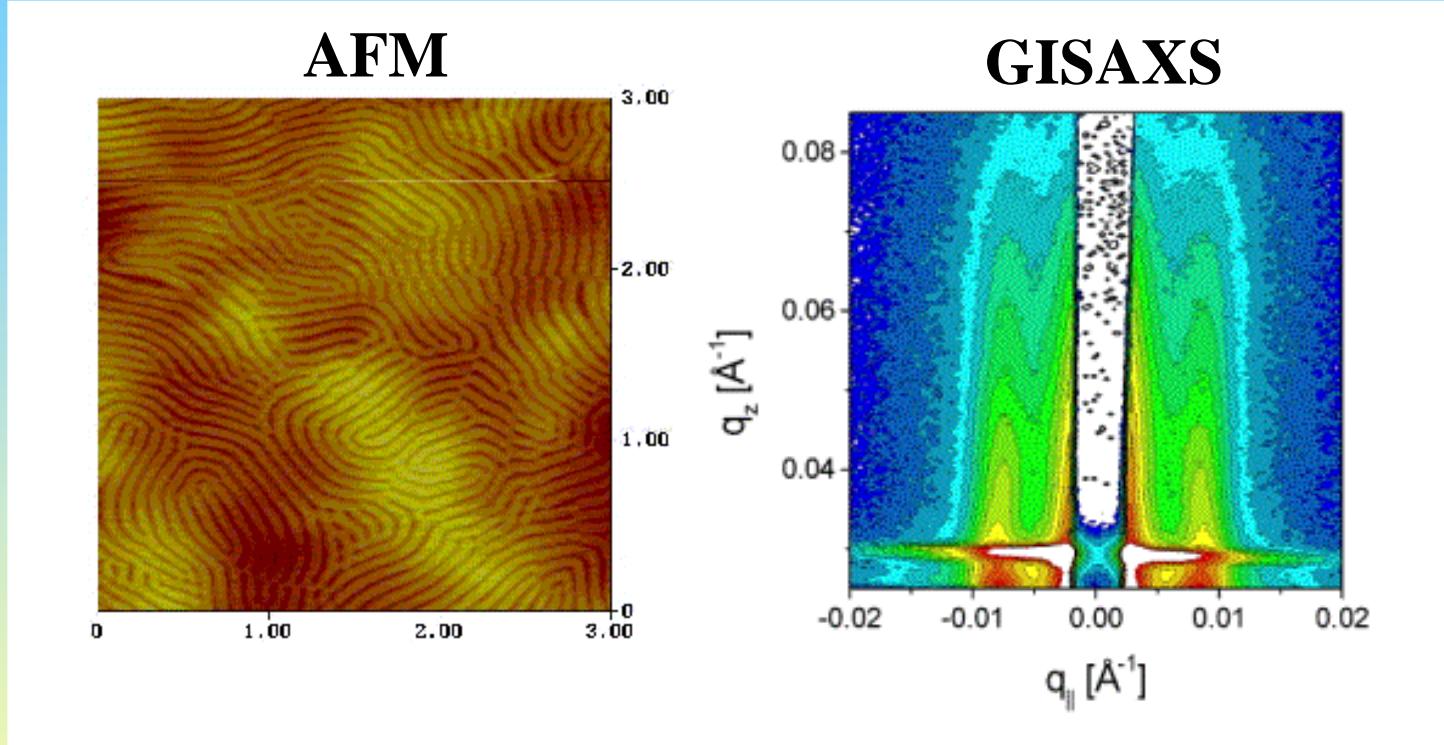
Polymer films: Smilgies *et al.*, SRN 15(5), p. 35-41 (2002).

What kind of information can we get ?



- internal structure of thin films
- lateral and normal density correlations
- preferential orientation
- form factors / finite size oscillations

Block copolymer thin films: PS-PB

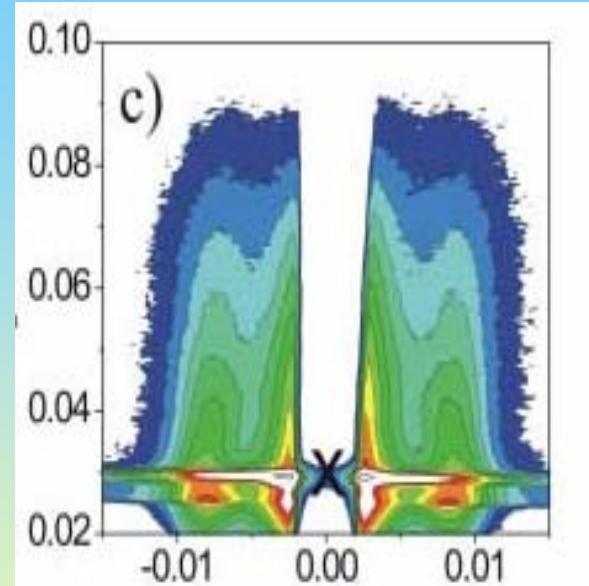
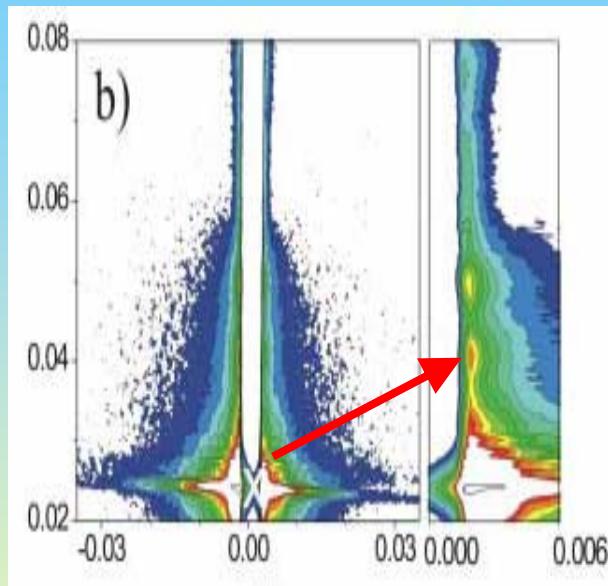


Smilgies, Busch, Posselt, Papadakis, SRN 15(5), p. 35-41 (2002).

Lamellar spacing: 850 Å
CHESS D-line: ML optics + CCD

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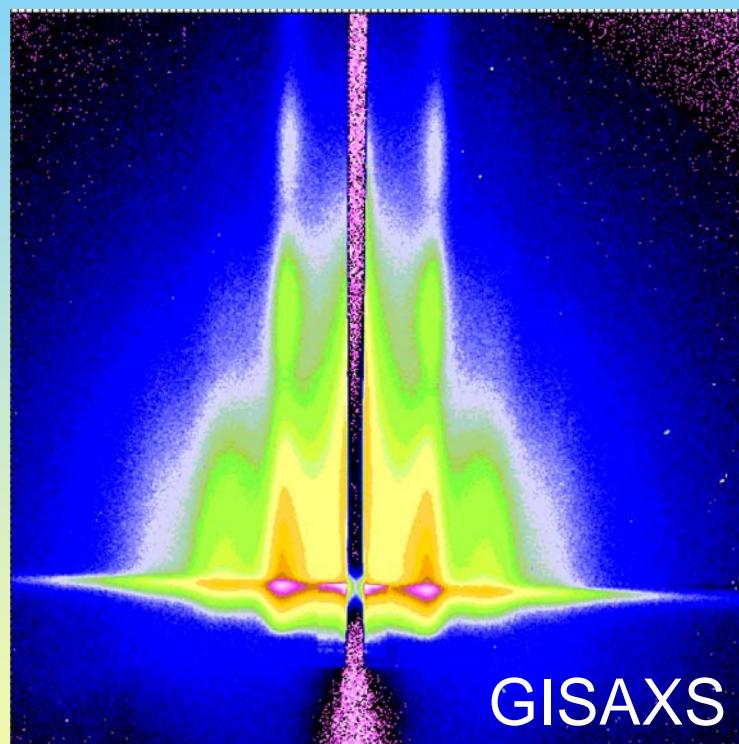
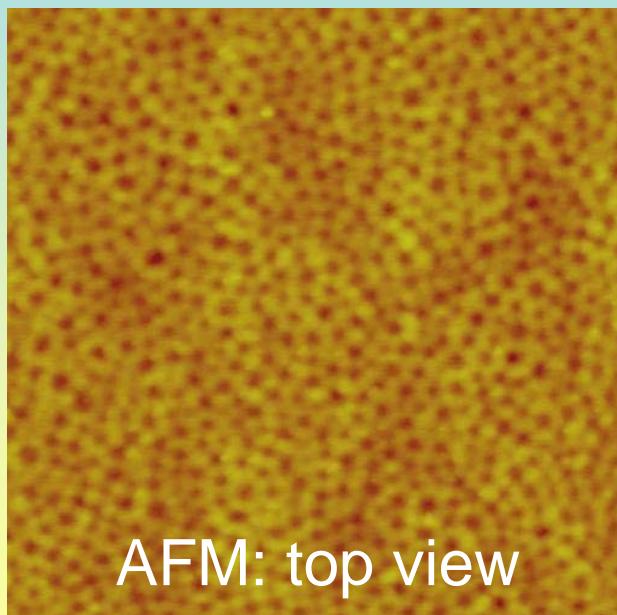
PS-PB: morphological transition



Papadakis, Busch, Posselt, Smilgies, Advances in Solid State Physics 44, 327-338 (2004).

PS-PB symmetric copolymer spin-cast on Si wafer:
short chains (< 30 kg/mol): parallel lamellae
long chains (>100 kg/mol): perpendicular lamellae

Nano-composites: voids in silica matrix via block copolymer + sol-gel process



- in-plane correlation peaks of the voids
- form factor oscillations of the voids

Du et al., Advanced Materials 16, 953-957 (2004).

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GISAXS assets

- non-invasive
- no special sample preparation
- sensitive to lateral and normal structure
- compatible with in-situ experiments
- real-time studies possible

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